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WILD RICE AND ITS CHEMICAL COMPOSITION[1]

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INTRODUCTION

Wild rice, a grass indigenous to North America, grows extensively in shallow lakes and sluggish streams from Lake Winnipeg in the North to the Gulf of Mexico in the South, and from the Atlantic Ocean to the Rocky Mountains.

Although wild rice had been collected by Peter Kalm in the American Colonies before 1753 according to Larsen (*15, pp. 43–44*),[2] it was not generally known to botanists until that year, when Linnaeus named it *Zizania aquatica*. Jenks (*12*) states that the Indians and early white settlers called it manomin, an Algonquian word meaning "good berry." Many common names later came into use when the English and French settled in the States bordering the Great Lakes. By the French it was known as "folle avoine." Some of the English names found in the literature for this plant are wild rice, Indian rice, squaw rice, Canadian rice, black rice, Indian oats, blackbird oats, wild oats, and water oats.

Carr (*4*) in 1895 reported that wild rice serves the Indians both as food and revenue; hence is of great economic importance to the various tribes of the Great Lakes region. Wild rice gradually has come into favor with the white man, and is available in many leading hotels and even in chain and family grocery stores far from the original source of supply.

The seed is nearly cylindrical and much thinner than that of the well-known types of common rice. The kernel varies considerably in length, averaging from 12 to 20 mm., and in color from gray green or yellow green to purplish black. Unlike common rice, the seed of wild rice cannot be stored dry and yet retain its viability. For food purposes wild rice like other grains should be kept cool and dry.[3]

The literature contains relatively little information regarding the chemical composition and the nutritive value of wild rice, or the variation in composition as affected by (1) maturity of the seed, (2) locality in which the rice is grown, and (3) the changes that take place as a result of parching. This investigation was undertaken to obtain information on these points as well as on the chemical composition of wild rice.

[1] Received for publication October 24, 1947.

[2] Italic numbers in parentheses refer to Literature Cited, p. 78.

[3] For more detailed information on the botany and history of wild rice see publications of C. E. Chambliss (*5, 6*).

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So far as the authors know, the first recorded analysis of wild rice was made in 1862 by Peters (*20, p. 459*), who reported that the seed contained 6.74 percent protein, and was made up of 12 percent hulls and 88 percent hull-free kernels.

The next reports on wild rice were made by Woll (*27*) of the Wisconsin Agricultural Experiment Station in 1899 and by Snyder (*22*) of the Minnesota Agricultural Experiment Station in 1900. Snyder reported the composition of one sample of seed and Woll that of one sample of sun-dried seed and one sample of parched seed. Woll stated that wild rice was richer in both protein and nitrogen-free extract than other cereals and hence should have a higher food value. The protein content of the three samples studied by Snyder and Woll averaged about twice that reported by Peters.

In 1924 Kennedy (*14*) of the Minnesota Agricultural Experiment Station reported the results of analyses of four samples of parched wild rice, two of which were obtained direct from Indians in the region of the Minnesota rice lakes and two from local markets. She supplemented her early chemical analyses with biological tests, and concluded that while wild rice is far superior to ordinary polished rice as a food, it is nevertheless not an adequate food, the dietary properties of wild rice being similar to those of the common cereals in that they contain protein of rather low biological value. It does, however, contain "vitamin B" in amounts adequate for animal growth. Kennedy found that wild rice contained the following inorganic elements: Calcium, 0.018 percent; magnesium, 0.080 percent; potassium, 0.055 percent; sodium, 0.064 percent; phosphorus, 0.424 percent; and sulfur, 0.252 percent.

HARVESTING

Because the seed of wild rice ripens unevenly, shatters readily, and is eaten by birds, not more than half of the crop is generally collected. According to Jenks (*12*), the grain is occasionally gathered while in the milk stage, and dried artificially. This process, however, destroys the germinating capacity of the seed. Stickney (*23*) states that just before harvesttime, in August, when the rice is in the early milk stage the Indian women go to the rice fields in canoes and tie as many stalks into bunches as possible to protect the grain from the birds and to prevent undue shattering. The person who ties the grain in bunches has a prior right to harvest it. At harvesttime the women return in their canoes to gather the rice. One woman holds the bunches over the boat with one hand and with the other hand strikes them with a stick, thus dislodging the oatlike grain which falls to the bottom of the boat. About one-fourth of the crop may thus be harvested at the first gathering. Repeated visits are made during harvesttime, which may last a month. Much of the grain that falls into the water becomes buried in the mud; the plants emerge early the following June, flower late in July, and form seed in September.

CURING AND THRESHING

Since the wild rice is naturally high in moisture when harvested and may also become wet during the processes of gathering and hauling in boats, it must be thoroughly dried or cured to permit safe

storage. Curing also facilitates subsequent removal of the closely adhering hulls by threshing.

According to Jenks (*12*) there are three ways in which the grain is cured by rice-gathering Indians. One is by drying in the sun, which requires the longest time. The most rapid, but also the most laborious, method is to parch the grain by heating it in a kettle or other vessel over a slow fire until the hulls are partly charred. Continuous stirring is required to prevent overheating. The method commonly used for the bulk of the crop is fire curing, in which the grain, spread in a thin layer on mats, is subjected to the smoke and heat from a slow fire while it is supported at a safe distance above the fire on crude scaffolding.

Parching is generally preceded by partial sun drying or fire curing. To hasten drying, the grain is occasionally shaken or turned. In parching, the kernels swell to about twice the size of the sun-dried grain and become somewhat translucent. Sometimes they crack open, but to a lesser degree than parched corn.

After being cured, the rice is subjected to a process of threshing to remove the hulls. The equipment for threshing is extremely primitive. It may be no more than a hole in the ground, about 1½ feet in diameter and 2 feet deep, lined with a skin, to serve as a mortar. The "pestle" is usually the Indian's moccasin-covered feet. The Indian treads upon the rice with a shuffling motion until the hulls are detached from the kernels. Fire-cured grain is generally flailed or pounded with a stick somewhat larger at one end. The last step is that of winnowing, or removal of the hulls from the grain, after which the wild rice is ready for consumption or for market. These primitive processes of curing wild rice and removing the hulls, as practiced by the Indians, are said to yield a better product than is obtained by the modern processes of the white man.

PLAN OF WORK AND PREPARATION OF SAMPLES

For this study 36 samples of wild rice were used.[4] All the samples, except one from Wisconsin, one from Canada, and one from Georgia, were obtained from the region of small lakes in northern Minnesota. Every effort was made to obtain as full and authentic information as possible regarding the conditions under which the rice was grown and the methods used in curing or parching it. Whenever possible, samples of the natural air-dried seeds as well as of parched seeds were collected from the same sources. Some of the samples obtained for this study were parched and threshed by the Indians of the region. A few of the samples had evidently been heated in a revolving drum after which the hulls were flailed off mechanically. The crude methods of removing the hulls, as practiced by the Indians, result in products differing appreciably in composition, since the amount of seed coat or bran removed with the hulls may vary considerably.

The hulls that were still attached to the seeds in some of the samples were removed in the laboratory by the use of a home-made hand-operated huller consisting of two small boards on each of which corrugated rubber was nailed. A mere rubbing of the rice between the

[4] These were collected in 1939 by C. E. Chambliss of the Bureau of Plant Industry, Soils, and Agricultural Engineering.

boards sufficed to loosen the hulls. The samples of grain were then carefully cleaned, all foreign material being removed before the grain was ground for analysis. The weight per 1,000 kernels and the percentage of hulls for some of the samples are recorded in table 1.

TABLE 1.—*Physical differences between original samples of wild rice*

Sample No.	Natural or unparched seed: Source [1] and description	Moisture	Hulls	Weight of 1,000 kernels [2]
		Percent	*Percent*	*Grams*
2	Mud Lake	9.28	19.84	19.78
4	Star Lake (not fully matured)	8.95	20.97	15.52
13	Height of land (divide)	9.42	17.71	17.77
14	Shell Lake [3]	8.95	17.59	20.36
17	Goose Lake	9.85	18.68	19.68
23	Nett Lake	10.05		32.37
25	Vermilion River	10.00		32.66
28	Moose Lake	9.18		29.96
30	Wasuch Lake	9.40		28.60
35	Big Rice Lake [3]	8.78		19.80
7	Rat Lake (ready to shatter)	9.77		
8	Laura Lake (not fully matured)	10.05	15.62	27.84
9	Minnewawa Lake (not fully matured)	9.00		35.86
10	Gull River	9.30	19.25	
11	Blackbird Lake	9.20	16.40	
19	Bowstring Lake (commercial)	9.38		22.65
36	Turpela Lake	9.70		
37	Ogeechee River, Ga.—(Seed longer and more needlelike than others)	8.65		

Sample No.	Parched seed: Source [1] and description	Moisture	Hulls	Weight of 1,000 kernels [2]
		Percent	*Percent*	*Grams*
3	Mud Lake	7.85	18.50	20.08
6	Star Lake (not fully matured) [4]	7.27		19.16
12	Height of land (divide)	7.75		17.80
15	Shell Lake [3]	8.99	17.28	
16	Goose Lake	8.85		24.06
24	Nett Lake [5]	9.31		46.66
26	Vermilion River [3]	9.16		34.50
27	Moose Lake	9.88		
29	Wasuch Lake [5]	8.38		34.80
34	Big Rice Lake [5]	9.80		19.74
18	Mole Lake, Wis.	9.00		
20	Dealer (some bran removed)	8.35		
21	Dealer	7.83		
22	do	8.65		
23	Dealer (most of bran removed)	8.15		20.73
32	Dealer (some of bran removed)	8.20		19.43
33	Dealer	7.67		26.20
38	Canada (commercial: about twice as large and heavy as other parched seeds)	9.30		56.35

[1] All localities in Minnesota, except as indicated.
[2] Hull-free.
[3] Hulled in laboratory.
[4] Parched in iron tub.
[5] Parched in iron kettle.

In most cases the weight per 1,000 kernels was less for the unparched seed than for the corresponding sample of parched seed. The Canadian parched seed (sample 38) weighed 56.35 gm. per 1,000 kernels, which was about twice the weight of seed grown in Minnesota. When five miscellaneous samples of unparched wild rice obtained from

Indians in Minnesota (samples 7, 8, 9, 11, and 36) were separated into mature portions and immature portions, the average weight per 1,000 kernels for the mature portion was 38.09, whereas that for the immature portion was 27.06.

The percentages of hulls, determined for 10 samples, were from one-fourth to three-fourths higher than the 12 percent reported by Peters (*20*).

METHODS OF ANALYSIS

For the most part the methods of the Association of Official Agricultural Chemists (*1*) were followed in making the chemical analyses. All determinations were made on hull-free samples. The kernels were finely ground, and the ground material was immediately placed in airtight bottles.

The moisture content was determined on the air-dried samples by drying the ground material at 130° F. for 1 hour. Sugars were determined by the Munson-Walker method. Calcium was determined as oxalate titrated against potassium permanganate; magnesium, gravimetrically as pyrophosphate; potassium, as chloroplatinate; sodium, by difference (subtracting the calculated weight of potassium chloride from the determined weight of potassium and sodium chlorides); phosphorus, volumetrically; sulfur, gravimetrically as barium sulfate after ashing the sample with magnesium nitrate; chlorine, volumetrically after ashing the sample with sodium carbonate; manganese, colorimetrically by the periodate method of Davidson and Capen (*8*); and copper, by the Biazzo method as modified by Elvehjem and Lindow (*10*). Other constituents, such as ether extract (fat), crude fiber, and protein, were determined by the methods of the Association of Official Agricultural Chemists.

ANALYTICAL RESULTS

The data on chemical composition of the samples of wild rice used in this investigation are given in table 2.

TABLE 2.—*Chemical compositions of natural (N) and parched (P) hull-free wild rice in percent*

[Air-dry basis]

SPECIALLY SELECTED SAMPLES

Sample No.		Source [1]	Moisture		Ether extract		Crude fiber		Protein (N×6.25)		Sugars [2]		Ash		Potassium		Sodium		Calcium		Magnesium		Phosphorus		Sulfur		Chlorine	
N	P		N	P	N	P	N	P	N	P	N	P	N	P	N	P	N	P	N	P	N	P	N	P	N	P	N	P
2	3	Mud Lake	9.28	7.85	0.75	0.46	1.15	0.96	14.88	14.22			1.41	1.25	0.272	0.274	0.063	0.065	0.029	0.018	0.108	0.102	0.361	0.321	0.178	0.167	0.050	0.043
4	6	Star Lake	8.95	7.27	.88	.70	1.35	1.18	16.50	15.81			1.65	1.55	.364	.291			.020	.020	.132	.090	.396	.317	.156	.122		.043
13	12	Height of land	9.42	7.75	.65	.53	1.08	.81	15.00	15.00	2.15	1.19	1.58	1.37	.332	.291	.039		.022	.023	.138	.096	.378	.317	.171	.116	.039	.035
14	15	Shell Lake	8.95	8.99	1.08	.99	1.13	.99	17.22	15.23			1.65	1.68	.374	.299	.053	.034	.023	.023	.144	.114	.409	.387	.139	.155	.035	.044
17	16	Goose Lake	9.85	8.85	.64	.57	1.22	.55	14.50	14.18	2.05	.70	1.57	1.18	.374	.273			.022	.018	.126	.084	.356	.273	.158	.127	.043	.043
23	24	Nett Lake	10.05	9.31	.69	.68	1.11	.85	14.00	12.81			1.46	1.29	.342	.291	.043	.066	.022		.132	.111	.360	.312	.130	.145	.027	.038
25	26	Vermilion River	10.00	9.16	.74	.40	1.11	.65	13.00	12.38	2.10	.35	1.52	1.11	.322	.267	.039	.033	.019	.021	.114	.095	.370	.294	.148		.053	.039
28	27	Moose Lake	9.18	9.88	.70	.60	.91	.91	14.09	12.75	1.82	.87	1.43	1.31	.315	.291		.065	.018	.015	.108	.107	.327	.321	.144	.114	.044	.039
30	29	Wasuch Lake	9.40	8.38	.50	.45	.93	.87	12.99	12.50	2.09	1.40	1.36	1.25	.332	.249	.037		.022	.020	.114	.102	.361	.321	.147	.121	.043	.044
35	34	Big Rice Lake	8.78	9.80	.80	.88	1.10	.94	15.61	14.91	2.71	1.28	1.67	1.43	.323	.244			.018		.126	.132	.392	.378	.168	.140	.043	.034
Average for 10 samples or as noted in parentheses.			9.39	8.72	.74	.63	1.11	.87	14.77	13.97	2.15 (6)	.96 (6)	1.53	1.34	.335	.277	.045 (6)	.053 (5)	.022	.020 (8)	.124	.103	.371	.324	.154	.134 (9)	.042 (9)	.040

MISCELLANEOUS SAMPLES

7	----	Rat Lake	9.77	----	0.76	----	0.95	----	13.30	----	----	----	1.48	----	0.339	----	----	----	----	----	----	----	0.338	----	0.146	----	----	----
8	----	Laura Lake	10.05	----	.85	----	1.00	----	14.50	----	----	----	1.61	----	.324	----	----	----	----	----	0.133	----	.398	----	----	----	----	----
9	----	Minnewawa Lake	9.00	----	.66	----	.96	----	13.25	----	----	----	1.35	----	.325	----	----	----	----	----	.107	----	.326	----	.140	----	----	----
10	----	Gull River	9.30	----	.53	----	1.07	----	15.36	----	----	----	1.65	----	.307	----	----	----	----	----	.210	----	.392	----	.155	----	----	----
11	----	Blackbird Lake	9.20	----	.78	----	1.20	----	14.44	----	----	----	1.60	----	.307	----	----	----	----	----	.150	----	----	----	.150	----	----	----
19	----	Bowstring Lake	9.38	----	.65	----	1.03	----	14.50	----	----	----	1.53	----	.355	----	----	----	----	----	.180	----	.364	----	.158	----	----	----
36	----	Turpela Lake	9.20	----	.54	----	1.00	----	13.64	----	----	----	1.50	----	.307	----	----	----	----	----	.195	----	.363	----	.158	----	----	----
37	----	Ogeechee R., Ga	8.65	----	.48	----	.90	----	13.94	----	----	----	1.33	----	----	----	----	----	----	----	.138	----	.299	----	.110	----	----	----
18	----	Mole Lake, Wis	----	9.00	----	0.56	----	0.73	----	13.37	----	----	----	1.17	----	----	----	----	----	----	----	0.126	----	0.298	----	0.120	----	----
20	----	Dealer [3]	----	8.35	----	.77	----	.90	----	14.15	----	----	----	1.50	----	0.344	----	----	----	----	----	.138	----	.352	----	.185	----	----
21	----	----do	----	7.83	----	1.11	----	1.14	----	14.75	----	----	----	1.64	----	----	----	----	----	0.016	----	----	----	.373	----	.161	----	----
22	----	----do	----	8.65	----	.99	----	1.10	----	14.39	----	----	----	1.70	----	.323	----	----	----	----	----	.132	----	.385	----	.159	----	----
31	----	----do [4]	----	8.15	----	.60	----	.65	----	14.81	----	----	----	1.43	----	.270	----	----	----	.017	----	.138	----	.308	----	.180	----	----
32	----	----do [3]	----	8.20	----	.78	----	.70	----	14.88	----	----	----	1.47	----	.192	----	----	----	----	----	.126	----	.338	----	.172	----	----
33	----	----do	----	7.67	----	.81	----	1.18	----	15.06	----	----	----	1.64	----	----	----	----	----	.017	----	.164	----	.400	----	.164	----	----
38	----	Canada	----	9.30	----	.50	----	.70	----	12.75	----	----	----	1.40	----	.266	----	----	----	.016	----	----	----	.317	----	.165	----	----
Average for 8 samples or as noted in parentheses.			9.32	8.39	.66	.77	1.02	.89	14.12	14.28	----	----	1.50	1.49	.324 (7)	.279 (5)	----	----	----	.016 (4)	.157	.137 (6)	.355 (7)	.346	.150 (7)	.163	----	----
Average for 18 samples or as noted in parentheses.			9.35	8.58	.71	.69	1.07	.88	14.48	14.11	2.15 (6)	0.96 (6)	1.51	1.41	.331 (17)	.278 (15)	0.045 (6)	0.053 (5)	0.022 (10)	.019 (12)	.139 (17)	.116 (16)	.364 (17)	.334	.152 (17)	.148 (17)	0.042 (9)	0.040 (10)

[1] All localities in Minnesota, except as indicated. [2] All sugars, expressed as invert sugar. [3] Some of surface coat removed. [4] Most of surface coat removed.

Of the 36 samples, 10 were of natural or unparched seed (N) and 10 were corresponding samples of parched seed (P) from 10 different localities in Minnesota. Of the remaining 16 miscellaneous samples, 8 were unparched seed obtained direct from the Indians, 7 coming from the Minnesota lake region and 1 from Georgia, and 8 were parched seed obtained from dealers. The parched samples for the most part were mixtures of wild rice grown in different lakes in Minnesota and such as might be obtained on the market generally. Some of these parched samples had not only the hulls removed, but also some of the bran. One sample was grown in Wisconsin and 1 in Canada, the latter being the best of the 36 samples with regard to size and general appearance of the grain. The rice grown in Georgia was also noteworthy; it was longer and more needlelike than the Minnesota or Wisconsin rice.

The data in table 2 show that the unparched seed is slightly richer in ash, ether extract, fiber, protein, sugars, and pentosans than the parched seed. The unparched seed is also slightly richer in phosphorus, potassium, magnesium, and sulfur, probably because more or less of the bran as well as the hull had been removed from the parched seed in the hulling process. Bran, of course, is relatively rich in most of the constituents mentioned. The process of parching wild rice, like that of roasting coffee, causes a considerable loss of sugar.

As shown in table 2, the composition of the 16 miscellaneous samples varies considerably in the percentage of most of the constituents, namely: ether extract, 0.48–1.11; crude fiber, 0.65–1.20; protein, 12.75–15.30; ash, 1.17–1.70; potassium, 0.192–0.355; magnesium, 0.107–0.195; phosphorus, 0,298–0.400; and sulfur, 0.120–0.185. These variations are largely due to differences in the maturity of the grain, the amounts of bran removed in the crude process of milling, and the environment under which the seed was grown.

The Canadian parched seed (sample 38) was appreciably lower in ether extract, crude fiber, protein, and potassium than the Minnesota seed. There was little difference between the composition of the Wisconsin and Georgia rice and that of the Minnesota rice.

In order to facilitate comparison, the minimum, maximum, and average results obtained in this investigation, together with all available results of previous analyses of wild rice, are grouped together in table 3, and the average results for the 18 samples of unparched wild rice and 18 samples of parched rice reported here, together with some analyses of cereals, buckwheat, and soybeans, are given in table 4.

Table 3 also gives the analytical results on three samples of hulls from wild rice. Hulls from one sample grown in Georgia and a composite sample of hulls from several samples of wild rice grown in Minnesota were analyzed in this investigation. The hulls from the Minnesota rice were markedly lower in fat and crude fiber. There was little difference between the two samples in protein and ash content. The other hull analysis, reported by Peters (*20*), showed considerably less protein, much more fiber, and somewhat more ash than were found by the authors.

[1] All localities in Minnesota, except as indicated. [2] All sugars, expressed as invert sugar. [3] Some of surface coat removed. [4] Most of surface coat removed.

TABLE 3.—*Summary of analyses of hull-free wild rice and hulls in percent on air-dry basis*

[Figures in parentheses indicate number of analyses made]

Year	Number of samples	Description and source of samples	Value selected	Moisture	Ether extract	Crude fiber	Protein (N×6.25)	Sugars [1]	Pentosans [2]	Ash	Potassium	Sodium	Calcium	Magnesium	Phosphorus	Sulfur	Chlorine	Manganese [3]	Reference
				Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	
1939	10	Unparched specially selected seed from 10 localities in Minnesota	Min	8.75	0.50	0.91	12.99	1.82	2.35	1.36	0.272	0.037	0.018	0.108	0.327	0.130	0.027	0.0006	(4)
			Max	10.05	1.08	1.35	17.22	2.71	2.89	1.67	.374	.063	.029	.144	.409	.178	.053	.0012	
			Avg	9.39	.74	1.11	14.77	2.16(6)	2.69(3)	1.53	.335	.045(6)	.022	.124	.371	.154	.042	.0009(5)	
1939	10	Parched seed from same 10 localities in Minnesota	Min	7.27	.40	.55	12.38	.70	1.70	1.11	.224	.033	.015	.084	.273	.114	.035	.0012	(4)
			Max	9.88	.99	1.18	15.81	1.40	1.93	1.68	.299	.066	.023	.132	.387	.167	.044	.0014	
			Avg	8.72	.63	.87	13.97	1.10(5)	1.83(3)	1.34	.277	.053(5)	.020(8)	.103	.324	.134	.040	.0013(6)	
1939	8	Unparched seed from Indians (1 sample from Ga.; others, Minn.)	Min	8.65	.48	.90	13.25			1.33	.307			.107	.299	.140			(4)
			Max	10.05	.85	1.20	15.36			1.65	.355			.210	.398	.158			
			Avg	9.32	.66	1.02	14.12			1.51	.324(7)			.157(7)	.355	.150		.0018(1)	
1939	8	Parched seed from dealers	Min	7.67	.50	.65	12.75			1.17	.192		.016	.126	.298	.120			(4)
			Max	9.30	1.11	1.18	15.06			1.70	.344		.017	.164	.400	.185			
			Avg	8.39	.77	.89	14.28			1.49	.279(5)		.016(4)	.137(6)	.346	.163			
	18	Unparched seed, specified above.	Avg	9.35	.71	1.07	14.48	2.16(6)	2.69(3)	1.51	.331(17)	.045(6)	.022(10)	.139(17)	.364	.152(17)	.042(9)	.0011(6)	(4)
	18	Parched seed, specified above.	Avg	8.58	.69	.88	14.11	1.10(5)	.183(3)	1.41	.278(15)	.053(5)	019(12)	.116(16)	.334	.148(17)	.040(10)	.0013(6)	
1939	5	Unparched seed from Indians in Minn. (selected from 7 samples)	Min	9.00	.54	.95	13.25			1.35	.307			.107	.326	.140			(4)
			Max	10.65	.85	1.20	14.50			1.61	.339			.181	.398	.158			
			Avg	9.44	.72	1.02	13.82			1.51	.320			.142(4)	.356(4)	.148(4)			
1939	5	Mature portions of same	Min	8.45	.40	.80	12.75			1.24	.274				.325	.132			(4)
			Max	8.87	.53	1.00	14.02			1.51	.291				.387	.170			
			Avg	8.68	.47	.92	13.37			1.37	.285				.349	.150			
1939	5	Immature portions of same	Min	8.48	.30	1.00	12.68			1.33	.291				.327	.129			(4)
			Max	8.70	.77	1.15	14.37			1.57	.365				.422	.144			
			Avg	8.60	.62	1.10	13.52			1.44	.326				.370	.136			
1939	1	Parched seed from Wisconsin.		9.00	.56	.73	13.37			1.17				.126	.298	.120			(4)
1939	1	Unparched seed from Georgia.		8.65	.48	.90	13.94			1.33				.138	.299	.140			(4)
1939	1	Parched seed from Canada		9.30	.50	.70	12.75			1.40	.266		.016		.317	.165			(4)
1939	1	Hulls from Minnesota seed (composite of several samples).		7.45	.55	21.70	8.81			[5]6.25									(4)
1939	1	Hulls from Georgia seed		8.28	1.05	31.30	9.05			[6]6.51									(4)
1862	1	Seed (source and treatment unknown).		12.00	.70	1.93	6.74			1.70									(7)
1862	1	Hulls from same		13.20	.83	38.90	2.82			9.20									(7)

1862	1	Hulls from same		13.20	.83	38.90	2.82			9.20										(7)
1899	1	Seed from Minnesota (treatment unknown).		9.29	.73	[8]4.89	12.50			1.42										(9)
1899	1	Seed, sundried, from Wisconsin.		9.99	.88	1.22	13.65			1.58										(10)
1899	1	Seed, parched, from Wisconsin.		9.54	.86	1.12	13.00			1.44										(10)
1915	4 2	Seed, parched, from Minnesota dealers.	Avg.	7.80	.67	1.40	13.67	3.34		1.24	.055	.064	.018	.080	.424	.252				(11)
	2	Seed, parched, from Minnesota Indians.	Avg.	8.38	.69	1.61	14.51	2.63		1.21										

[1] All sugars, expressed as invert sugar.
[2] Individual values for unparched samples 4, 13, and 17 were 2.35, 2.82, and 2.89, respectively; individual values for parched samples 6, 12, and 16 were 1.91, 1.93, and 1.70 respectively.
[3] Individual values for unparched samples 8, 13, 14, 17, 23, and 28 were 0.0018, 0.0012, 0.0006, 0.0012, 0.0006, and 0.0011; individual values for parched samples 12, 15, 16, 24, 26, and 27 were 0.0012, 0.0012, 0.0014, 0.0012, 0.0012, and 0.0014.
[4] Bureau of Agricultural and Industrial Chemistry (Capen).
[5] 84 percent of the ash was insoluble in hydrochloric acid.
[6] 75 percent of the ash was insoluble in hydrochloric acid.
[7] Peters (*20*).
[8] Excessively high value might indicate typographical or experimental error.
[9] Snyder (*22, p. 500, table LXXI*).
[10] Woll (*27*).
[11] Kennedy (*14*).

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TABLE 4.—*Comparative chemical composition of wild rice and certain cereals and other seeds*

[Italic figures in parentheses, which refer to literature cited, indicate source from which data were obtained]

Description of sample	Moisture	Ether extract	Crude fiber	Protein (N x 6.25)	Sugars [1]	Pentosans	N-free extract [2]	Ash	Potassium	Sodium
Wild rice: [3]	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Unparched [4]	9.35	0.71	1.07	14.48	2.16	2.69	72.88	1.51	0.331	0.045
Parched [4]	8.58	.69	.88	14.11	1.10	1.83	74.33	1.41	.278	.053
Cultivated rice:										
Paddy [4 6]	12.84	1.48	7.65	6.88	.98	5.16	66.09	5.06	.224	
Brown [3 4]	12.09	1.63	.83	7.76	.68	2.00	76.54	1.15	.183	.043(*15*)
Polished [4]	13.00	.24	.20	7.25	.30	1.36	78.92	.39	.130	
Glutinous [4]	11.50	1.40	1.20	6.62			78.03	1.25		
Wheat: [7]										
Hard winter [4]	9.50	2.00	2.20	13.10	2.50	7.50	71.29	1.91(*9*)	.515	.009(*24*)
Soft winter [4]	9.50	2.00	2.10	10.30	3.00	7.00	74.32	1.78(*9*)	.399(*25*)	.009(*26*)
Barley: [8]										
Two-row (*16*)	8.92	2.01	5.23	12.94		8.41	68.02	2.88	.598	.021(*26*)
Six-row (*16*)	8.71	2.02	5.70	11.86		9.64	68.73	2.98	.591	
Rye: [4]	11.00	1.70	2.00	11.60	4.00	8.50	71.40	2.30	.573(*26*)	.019(*26*)
Oats:										
Unhulled [4]	11.60	4.70	11.00	13.00	1.50	12.00	56.30	3.40	.423(*26*)	.070(*26*)
Oat groats	8.00	7.00	1.00	15.00	1.50		67.12	1.88	.344(*21*)	Trace(*21*)
Corn:										
Dent [4]	10.50	4.82	1.74	10.65	1.80	5.00	70.79	1.50	.380(*26*)	
Flint (*7*)	11.31	4.99	1.35	10.52			70.39	1.44		
Popcorn (*7*)	10.71	5.18	1.76	11.22			69.66	1.47		
Buckwheat:										
Unhulled [4]	11.70	2.50	10.06	11.90	1.20	6.50	61.84	2.00	.397(*17*)	.074(*17*)
Buckwheat groats [4]	10.50	2.85	.80	13.30			70.84	1.71	.394	
Soybeans [4]	7.0	18.50	4.00	36.00	8.00	4.50		5.20	1.984(*19*)	.123(*19*)
Grain sorghum [4]	9.50	3.50	1.80	13.30	1.00	4.80		1.65	.373(*3*)	.013(*3*)

Description of sample	Calcium	Magnesium	Phosphorus	Sulfur	Chlorine	Silicon	Iron	Aluminum	Manganese	Copper
Wild rice: [3]	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*P.p.m.*
Unparched [4]	0.022	0.139	0.364	0.152	0.042				0.0011	[5] 3.2
Parched [4]	.019	.116	.334	.148	.040				.0013	[5] 2.6
Cultivated rice:										
Paddy [4] [6]	.050	.092	.380	.078(*9*)	.047(*9*)	1.910				
Brown [3] [4]	.021	.070	.190	.014(*9*)	.027(*9*)	.089	.0145(*13*)			
Polished [4]	Trace	.018	.053	.075(*9*)	.024(*9*)	.020				
Glutinous [4]										
Wheat: [7]										
Hard winter [4]	.050	.144	.440(*9*)	.150(*9*)	.031(*9*)	.006(*24*)	.0031(*24*)	0.0003(*24*)	.0024(*24*)	6(*24*)
Soft winter [4]	.036(*25*)	.129(*25*)	.387(*9*)	.111(*9*)	.070(*9*)	.008(*25*)	.0031(*25*)	.0009		
Barley: [8]										
Two-row (*16*)	.057	.132	.330(*9*)	.116(*9*)	.189(*9*)	.025(*26*)	.051(*26*)			
Six-row (*16*)	.057	.132	.426(*9*)	.095(*9*)	.178(*9*)					
Rye: [4]	.050(*26*)	.136(*26*)	.471(*9*)	.127(*9*)	.051(*9*)	.007(*26*)	.011(*26*)			
Oats:										
Unhulled [4]	.085(*26*)	.133(*26*)	.488(*9*)	.200(*9*)	.068(*9*)	.598(*26*)	.064(*26*)			
Oat groats	.800(*21*)	.092(*21*)	.333(*21*)			.014(*21*)	.0038(*11*)			5(*11*)
Corn:										
Dent [4]	.020(*26*)	.126(*26*)	.369(*9*)	.091(*9*)	.039(*9*)	.016(*26*)				
Flint (*7*)										
Popcorn (*7*)										
Buckwheat:										
Unhulled [4]	.060(*17*)	.152(*17*)	.334(*9*)	.114(*9*)	.019(*9*)	.373(*26*)	.079(*26*)			
Buckwheat groats [4]	.015	.210	.350	.118	Trace		.0018		.0017	7
Soybeans [4]	.025(*2*)	.234(*19*)	.648(*9*)	.291(*9*)	.130(*9*)	Trace(*26*)	.0074(*18*)	.0018(*18*)	.0028(*18*)	12(*18*)
Grain sorghum [4]	.021(*3*)	.172(*3*)	.312(*3*)			.016(*3*)	.0175(*3*)			

[1] Total, as invert sugar.
[2] Includes sugars, pentosans, starch, etc.
[3] Hull-free.
[4] Unpublished data from Agricultural Chemical Research Division, Bureau of Agricultural and Industrial Chemistry.
[5] Individual values for unparched samples 14, 17, and 35 were 3.2, 3.1, and 3.2, respectively; individual values for parched samples 16, 34, and 37 were 2.3, 2.5, and 3.1, respectively.
[6] With hulls.
[7] Zinc in hard wheat, 0.01 percent (*24*): zinc in soft wheat, 0.0031 percent (*25, p. 75*).

The results on mature and immature portions of five samples of unparched wild rice from Indians in Minnesota indicate that fat, fiber, ash, potassium, and phosphorus decrease as the seed matures. The mature seed is only slightly poorer in protein and is somewhat higher in sulfur than the immature seed.

The process of parching wild rice was expected to produce changes in the nitrogen compounds. Therefore a few samples of unparched and parched wild rice were examined to determine the differences in their nitrogen-compound fractions. The results, given in tables 5 and 6, show that the salt-soluble and globulin-albumin portions undergo a slightly greater change than the other nitrogen compounds as a result of parching.

The processes of parching and separating the hulls were also expected to reduce the vitamin B_1 content. While the heat of parching may destroy some of the thiamine (vitamin B_1) in the seed, a loss of bran would also result in a corresponding loss of this and other B vitamins as well as of protein, fat, fiber, and ash. This is indicated by the results given in table 7.

It may be noted from this table that the parched seed, in comparison with the corresponding unparched seed, was not only lower in thiamine, but also in fat, fiber, protein, sugar, ash, and ash-forming constituents. These differences in composition indicate that the sample which had been parched (presumably at a high temperature) lost an appreciable amount of bran during the hulling process, leaving the seed higher in starch and lower in the constituents that occur principally in the bran.

TABLE 5.—*Water-, alcohol-, and salt-soluble nitrogen of parched wild rice*

Sample No.	Source	Nitrogen soluble in—			
		Water	70-percent alcohol	5-percent K_2SO_4	1-percent NaCl
		Percent	*Percent*	*Percent*	*Percent*
1	Goose Lake, Minn	0.06	0.06	0.16	0.15
16	Do	.04	.055	.115	.10
5	Star Lake, Minn	.05	.025	.16	.095
6	Do	.075	.065	.15	.105
12	Height of land, Minn	.085	.07	.18	.155

TABLE 6.—*Forms of nitrogen in (hull-free) unparched and parched seed*

Sample No.		Total nitrogen		Protein nitrogen		Nonprotein nitrogen		Salt-soluble nitrogen		Nonbasic amino nitrogen		Globulin and albumin	
Unparched	Parched	Unparched	Parched	Unparched	Parched	Unparched	Parched	Unparched	Parched	Unparched	Parched	Unparched	Parched
		Per-cent	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*
17	16	2.32	2.27	2.07	2.05	0.25	0.22	0.20	0.13	0.07	0.08	0.13	0.05
23	24	2.24	2.09	2.16	2.02	.08	.07	.31	.24	.04	.05	.27	.19
25	26	2.07	1.98	1.97	1.90	.10	.08	.43	.11	.06	.05	.37	.06
Average		2.21	2.11	2.07	1.99	.14	.12	.31	.16	.06	.06	.26	.10

TABLE 7.—*Composition of wild rice samples of relatively high and low thiamine content*

[Air-dry basis]

Constituent		Sample No. 25 (unparched seed)	Sample No. 26 (parched seed)
Thiamine	I. U. per gm.	2.00	1.08
Fat (ether extract)	percent	.74	.40
Fiber	do.	1.11	.65
Protein (N×6.25)	do.	13.00	12.38
Sugar (total as invert)	do.	2.10	.35
Ash	do.	1.52	1.11
Potassium	do.	.322	.267
Magnesium	do.	.114	.095
Phosphorus	do.	.370	.294
Chlorine	do.	.053	.039

Likewise, a comparison of the data for unparched and parched samples in table 2 shows that quite generally the parched seed is lower in the nonstarch constituents than is the unparched seed. However, in samples of unparched and parched seed which were examined elsewhere [5] for thiamine the International Units per gram amounted to 0.44 and 1.58 for two unparched samples while two corresponding samples of parched seed yielded 1.47 and 1.61 I. U. Evidently the parching had been carried on at a relatively low temperature; otherwise the loss of thiamine would have been appreciable, as was the case with sample 26 (table 7).

While no specific attempt has been made to compare the composition of the bran of wild rice with that of the hulls, it is generally accepted that bran of cereals is far richer than their hulls in all of the essential nutritive factors. Hence when considerable bran is removed as sometimes happens during the separation of the hulls, or during subsequent milling, the resultant more or less refined product is appreciably poorer in protein, fat, and minerals as well as in vitamins.

No noticeable differences in composition were observed between wild rice grown in sluggish streams and that obtained from lakes.

Wild rice is much richer than the commercial product known as brown rice (the cultivated rice from which the hulls have been removed) in protein, sugar, ash, magnesium, potassium, sodium, phosphorus, sulfur, and chlorine. Only in the fat content is wild rice poorer than brown rice. In fact, wild rice contains more protein than the average samples of wheat, barley, rye, corn, oats, buckwheat, or sorghum, but in other respects the composition of wild rice agrees fairly well with that of the other seeds just mentioned.

DISCUSSION AND SUMMARY

In general, because of the fact that the process of parching wild rice may result in the sloughing off of a more or less indefinite amount of bran (besides removing the hull), the tendency is for the unparched seed to contain a slightly greater percentage of fat, fiber, protein, sugar, pentosans, ash, and most of the individual mineral constituents than the parched seed. The percentage of protein in wild rice as

[5] The thiamine determinations were made by the General Mills Research Laboratory, Minneapolis, Minn.

reported by Peters (*20*) was approximately one-half that of the average of the 36 samples here recorded. The fiber content of wild rice as reported by Snyder (*22*) is about four times that of the average of the 36 samples. This might indicate that the particular seed as analyzed included the hulls, except for the fact that the percentages of protein, fat, and ash reported by Snyder are approximately the same as the average of the 36 samples here recorded.

Kennedy (*14*) reported 0.055 percent of potassium in wild rice, or less than one-fifth of the values found in the present study. On the other hand, she reported a considerably higher percentage of sulfur than that found in any of the writers' 36 samples.

Wild rice as gathered by Indians contains a considerable quantity of immature seed. Judging from the analysis of five samples of mature and five of immature seeds, recorded herein, it would seem that there is very little difference in the chemical composition of the two types of rice, although the mature seed does contain slightly less fat, fiber, protein, and ash constituents than the immature seed. The mature seed is fully one-third heavier than the immature seed, for during the ripening of cereals there is a certain amount of starch accumulation, which lowers the relative content of other constituents.

The locality where the wild rice was grown did not affect the chemical composition appreciably. The one sample of Canadian parched wild rice (an exceptionally fine commercial product) was almost twice as large and heavy as the average parched samples obtained from the Minnesota lakes. The fact that this seed was so large probably explains why its contents or fiber and protein were appreciably lower than those of the Minnesota seed. No material difference in appearance of the seed or in the chemical composition was noted between the one Wisconsin sample and the Minnesota seed. The single sample of seed from Georgia was more needlelike in appearance, although the chemical composition was practically the same as that of the Minnesota seed.

The ash of wild rice is slightly alkaline, 4 cc. of normal acid being required to neutralize ash from 100 gm. of hulled seed.

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POD MOTTLE, A VIRUS DISEASE OF BEANS [1]

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INTRODUCTION

In a survey of diseases of beans (*Phaseolus vulgaris* L.) near Charleston, S. C., in 1945, severely mottled pods were observed on several plants of the Tendergreen variety. It was suspected that the mottling was caused by the virus of southern bean mosaic (bean mosaic virus 4, *Marmor laesiofaciens* Zaum. and Harter) (*6*, *7*).[2] However, inoculations of the Pinto variety of bean with expressed juice from the mottled pods produced local lesions unlike those produced on it by the southern bean mosaic virus. Inoculations of other varieties also showed differences not only in the local lesions produced by the two viruses but also in varietal susceptibility. The systemic-mottled symptoms produced by these viruses on leaves were difficult to differentiate.

Nothing is known about the distribution of this virus under field conditions or about its economic importance. Since this virus is readily transmitted mechanically, it is not unlikely that it could be spread by field laborers, by farm machinery such as cultivators, by wind-blown sand, and by other means.

This paper reports the results of a study of the new virus in comparison with southern bean mosaic virus, which it most closely resembles. The data presented, which are the basis for the identification of this virus, show how it differs from similar viruses. Because of the extreme mottling that this virus produces on the pods of certain systemically infected varieties, the disease produced by it is called pod mottle. The name proposed for the virus conforms to Holmes' system of virus classification (*3*).

METHODS AND MATERIALS

The studies reported herein were conducted under greenhouse conditions at Beltsville, Md., at temperatures ranging from 21° to 27° C. The bean plants were inoculated when the primary leaves were not quite fully expanded, 10 to 12 days after planting. Carborundum powder No. 320 was used as an abrasive in transferring the viruses, and the residue was removed by washing the rubbed leaves with a fine spray of water. This procedure was used throughout except in the dilution studies discussed in the section Properties of Pod Mottle Virus. The methods used were similar to those employed in previous investigations (*7*).

The stock of pod mottle virus, which was collected in 1945, had been stored in a frozen condition for 16 months. The stock of southern

[1] Received for publication October 29, 1947.

[2] Italic numbers in parentheses refer to Literature Cited, p. 96.

bean mosaic virus came from infected pods received from Louisiana in 1940, the same source as the original virus (*6*, *7*). This virus had been stored in a frozen condition for 2 years. Both viruses produced severe infection after these periods of storage. The viruses were maintained on young, greenhouse-grown bean plants, and the inoculum was prepared from systemically infected plants.

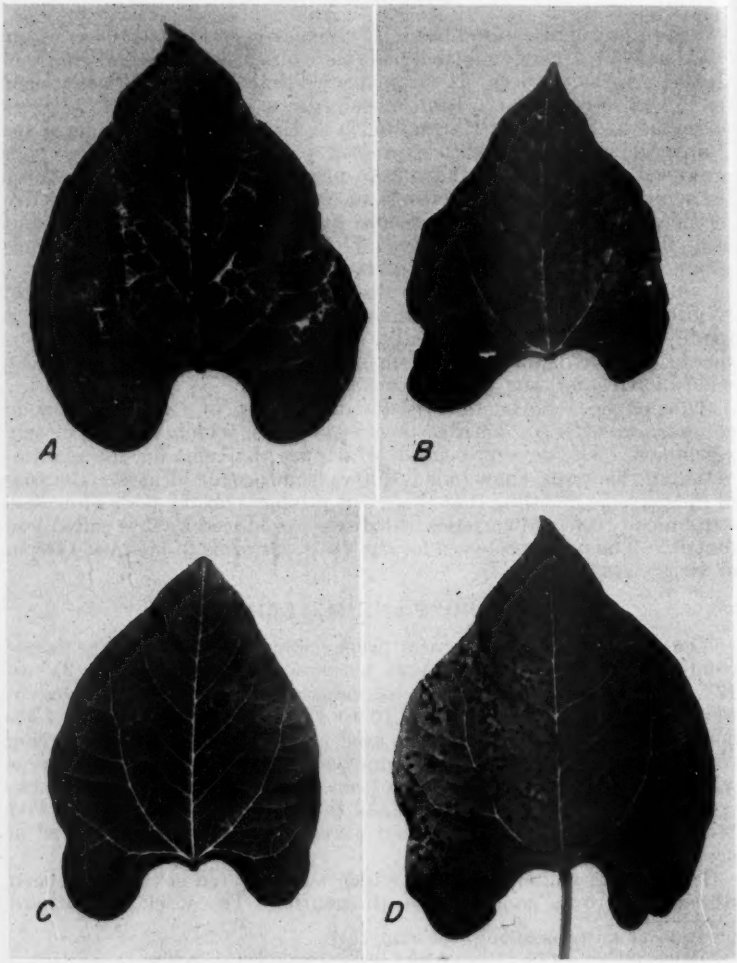

FIGURE 1.—Local lesions produced by southern bean mosaic and pod mottle viruses on leaves of the Idaho Pinto variety of bean. *A*, Southern bean mosaic virus. *B* and *C*, Pod mottle virus. In *C* note necrosis of veins. *D*, Southern bean mosaic virus on left half of leaf and pod mottle virus on right half.

EXPERIMENTAL RESULTS

SYMPTOMS

Like the southern bean mosaic virus, the pod mottle virus produces local lesions on some varieties of bean and systemic mottle on others. Varieties susceptible to local infection by the pod mottle virus are immune from systemic infection, and those susceptible to systemic infection are immune from local infection. The local lesions (fig. 1, *B*), which are somewhat circular, appear 3 or 4 days after inoculation. They are lighter brown and more diffuse than those produced by southern bean mosaic virus and give the impression of being subepidermal (fig. 1, *B* and *C*). They do not have light centers, as do those of southern bean mosaic (fig. 1, *A* and *D*), and range from 1 to 2.5 mm. in diameter, averaging about 2 mm. The size of the lesions depends on the variety, the age of the inoculated leaf, and the number of lesions per unit area. On certain varieties, such as most of the Refugees, the local lesions are extremely small and never numerous. In general, the edges of the lesions are not clearly defined. When the lesions are located near the veins and veinlets, the vascular tissue becomes necrotic (fig. 1, *C*).

The systemic-mottle symptoms of pod mottle (fig. 2, *A*, *B*, *C*) are in general more intense than those of southern bean mosaic (fig. 2, *D*), and on certain varieties such as Longreen and Tendergreen they are more severe than those of common bean mosaic. The range of symptoms includes those produced by common and southern bean mosaic viruses, but the symptoms are seldom as intense as those produced by the common bean mosaic virus on the very susceptible varieties such as Stringless Green Refugee and common Pinto. Infected leaves of very susceptible varieties are malformed and mottled (fig. 2, *A* and *C*), sometimes with considerable chlorosis (fig. 2, *B*), but they show no puckering or blistering. The trifoliate leaves of some varieties such as Full Measure and Tendergreen are both mottled and necrotic and may die. It is often difficult to differentiate the three viruses by systemic symptoms alone.

On the pods, pod mottle virus produces more marked symptoms than does southern bean mosaic virus. Infected pods of many susceptible varieties are severely mottled (fig. 3) and are darker green than normal. They are also shorter than normal and are decidedly malformed, being curled, twisted, and somewhat rough and warty; often they contain abortive or abnormally developed ovules.

FACTORS THAT AFFECT INFECTION

Infection was more readily obtained with pod mottle virus than with common bean mosaic virus, but local-lesion production was not quite so readily obtained as with southern bean mosaic virus. Although carborundum powder was used in the routine inoculations, just as good infection was obtained without its use. In practically all the inoculations when relatively young leaves were rubbed with the expressed virus juice, all the plants became either locally or systemically infected, depending on the variety inoculated. The local lesions produced by the pod mottle virus were never so numerous as those produced by southern bean mosaic virus.

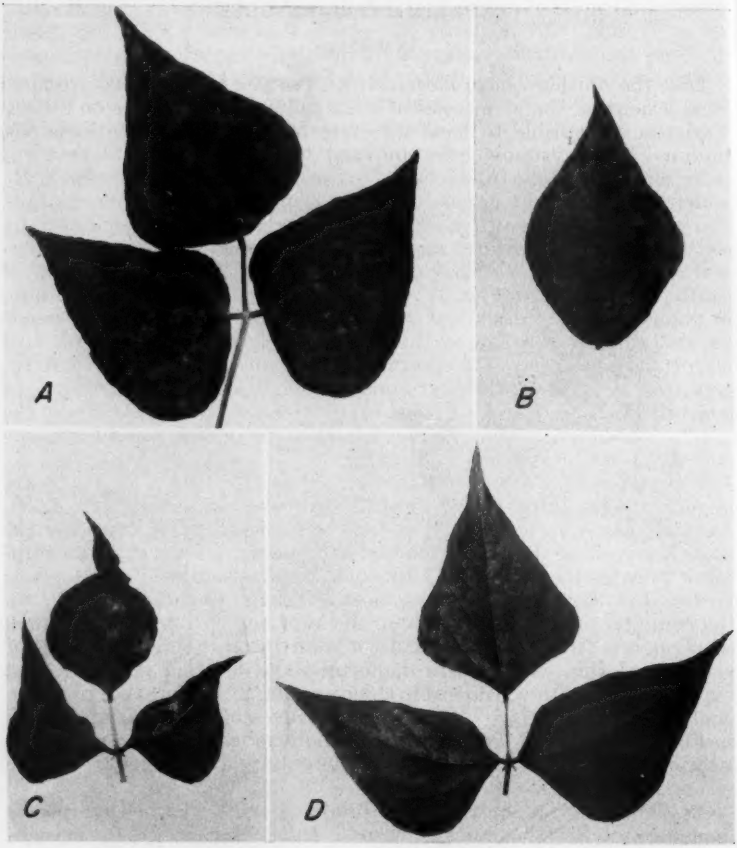

FIGURE 2.—Systemic mottle caused by pod mottle virus on trifoliate leaves of several varieties of bean: *A*, Longreen; *B*, Tendergreen; *C*, Dwarf Horticultural. *D*, Very mild symptoms of southern bean mosaic on a trifoliate leaflet of the Dwarf Horticultural variety.

Infection resulted when the simple leaves of Idaho Pinto bean were sprayed with expressed juice containing the virus. In 1 experiment 24 leaves were sprayed at each of 4 pressures, 5, 10, 20, and 25 pounds. All the sprayed leaves became infected. The average number of local lesions produced per leaf was 3, 4, 23, and 25, respectively. The checks, which were rubbed in the usual manner with an extract of the virus, had approximately 250 lesions per leaf. Leaves sprayed in the same manner with southern bean mosaic virus had about 5 times as many lesions per leaf as those sprayed with the pod mottle virus.

Handling plants systemically infected by pod mottle virus and then healthy plants of varieties susceptible to local infection, as bean pickers handle plants in the field, produced local lesions on such susceptible

plants. By using the same treatment with southern bean mosaic virus, more abundant local lesions were produced, apparently indicating that this virus is more highly infectious than pod mottle virus. These viruses, however, are much more infectious than common and yellow bean mosaic viruses.

The age of inoculated leaves has a definite influence on the appearance of the local lesions produced by the pod mottle virus. This was demonstrated by inoculating 12 simple leaves of Pinto bean plants at each of the following periods after planting: 12, 14, 15, 16, 19, and 21 days. The lesions on the leaves inoculated 12 and 14 days after planting were large (1.5 to 2 mm. in diameter) and fairly numerous. They were also abundant, but slightly smaller, on the leaves inoculated 15 and 16 days after planting. On the simple leaves inoculated 19 days after planting the lesions were very sparse and small, whereas on the young trifoliate leaves of these plants inoculated at the same time they were abundant and moderate in size. Only a few small local lesions were produced on the simple leaves inoculated 21 days after planting, but on the trifoliate leaves inoculated at the same time they were numerous and medium-sized (1.0 to 1.5 mm. in diameter).

Southern bean mosaic virus reacted similarly to pod mottle virus up to 16 days after planting, but the lesions produced by it were more numerous than those produced by pod mottle virus. Only an occa-

FIGURE 3.—Pods of Longreen variety infected by pod mottle virus.

sional lesion was produced on the simple leaves inoculated 19 and 21 days after planting, but on the trifoliate leaves of these plants the lesions were numerous and large.

RELATION OF TEMPERATURE TO LOCAL-LESION EXPRESSION

The influence of temperature on the expression of local infection by pod mottle and southern bean mosaic viruses was ascertained in a preliminary way by placing Pinto bean plants inoculated with these viruses in three greenhouses maintained at various temperatures. Greenhouse 1 (cool) was maintained at 10° C. at night and 21° to 24° during the day, greenhouse 2 (medium) was kept at 18° to 21° at night and 21° during the day, and greenhouse 3 (warm) was held at 27° day and night.

After 3 days pod mottle virus produced abundant local lesions on the plants in houses 2 and 3, but on those in house 1 the lesions were barely visible. During the same period southern bean mosaic virus produced lesions on plants in house 3 only.

At the end of 6 days the local lesions caused by pod mottle virus on the inoculated leaves in houses 2 and 3 were large and well-developed, whereas in house 1 the lesions were abundant but not so well developed as they were at higher temperatures. In house 3 there were considerable vein necrosis and killing of the inoculated leaves. The lesions had coalesced and were difficult to measure, but they were approximately 2 mm. in diameter. The lesions on the leaves of plants in houses 1 and 2 were 0.75 to 1 mm. and 2 mm. in diameter, respectively. After 6 days southern bean mosaic virus had produced the largest lesions, ranging from 1 to 1.5 mm. in diameter in house 3, but they were not numerous. In house 2 they were fairly large, ranging from 0.5 to 1 mm. in diameter, and very numerous. In house 1 the lesions were sparse and ranged from 0.75 to 1 mm. in diameter.

In order to determine more accurately the influence of temperature on the production of local lesions by pod mottle virus, inoculated detached leaves of Idaho Pinto bean were placed in petri dishes containing a 10-percent sugar solution. The dishes were kept in dark chambers maintained at temperatures ranging from 10° to 37° C. The results are recorded in table 1.

TABLE 1.—*Influence of temperature on the development of local lesions caused by pod mottle virus on detached leaves of Idaho Pinto variety of bean*

[Averages based on 3 leaves]

Temperature (° C.)	Time for lesion development	Lesions 7 days after inoculation [1]
	Days	*Number*
10		0
14	7	(2)
18	4	52± 8
22	3	151±44
26	2	108±38
30	3	(2)
37		(3)

[1] Number after ± is standard error.
[2] Indistinct.
[3] Leaves dead; no data obtained on local-lesion production.

The optimum temperature observed for the production of local lesions by this virus was 22° C. Although the lesions appeared about as rapidly at 30° as they did at 18° and 22° and 1 day later than at 26°, they were indistinct and impossible to count. None appeared at 10°.

SUSCEPTIBILITY TESTS

Reaction of Snap and Dry Bean Varieties

Practically all the commercially important varieties of snap and dry beans were inoculated with the pod mottle virus. The results of these inoculations, together with the varietal reactions to southern bean mosaic virus, are given in table 2. Of the 68 varieties or strains inoculated with pod mottle virus, 41 were homozygous for susceptibility to local lesions, 23 were homozygous for susceptibility to systemic infection, and 4 were heterozygous. As with southern bean mosaic, varieties that were homozygous for susceptibility to local lesions were immune from systemic infection. Sixteen of the twenty-three varieties that were homozygous for susceptibility to systemic infection were severely infected and 7 were mildly infected. The 4 varieties heterozygous for susceptibility were also mildly infected.

The majority of the green-podded varieties of snap and dry beans were susceptible to local infection. Most of the wax varieties were susceptible to systemic infection. In general, the reaction of most of the green-podded bush varieties of snap bean to pod mottle virus was different from that to southern bean mosaic virus. Most of the green-podded pole varieties of snap bean and the varieties of dry bean showed the same type of reaction to both viruses.

Table 2.—*Reaction of snap and dry bean varieties to inoculation with pod mottle and southern bean mosaic viruses*

Group and variety or strain	Plants showing [1]				Degree of systemic infection caused by—	
	Local lesions caused by—		Systemic infection caused by—			
	Pod mottle virus	Southern bean mosaic virus	Pod mottle virus	Southern bean mosaic virus	Pod mottle virus	Southern bean mosaic virus
Green-podded snap beans (bush):						
Bountiful	+	−	−	+		Moderate.
Burpee Stringless Green Pod	+	−	−	+		Mild.
Canadian Wonder	[2] −	−	+	+	Mild	Severe.
Commodore	[3] +	−	−	+		Do.
Dixie White	+	−	−	+		Mild.
Florida Belle	[3] +	−	−	+		Do.
Full Measure	−	−	+	+	Severe [4]	Severe.
Giant Stringless Green Pod	+	−	−	+		Mild.
Goddard	−	−	+	+	Mild	Do.
Horticultural, Dwarf	−	−	+	+	Severe [4]	Severe.
Landreth Stringless Green Pod	−	−	+	+	do	Mild.
Logan	[3] +	−	−	+		Do.
Longreen	−	−	+	+	Severe [4]	Do.
Low Champion	−	±	+	∓	do	Severe.
Plentiful	−	−	+	+	do	Moderate.
Ranger	+	+	−	−		
Refugee, Corbett	[3] +	+	−	−		
Refugee, Idaho	[3] +	−	−	+		Mild.
Refugee, Medal	[3] +	−	−	+		Do.
Refugee, Sensation No. 1066	[3] +	−	−	+		Do.

See footnotes at end of table.

TABLE 2.—*Reaction of snap and dry bean varieties to inoculation with pod mottle and southern bean mosaic viruses*—Continued

Group and variety or strain	Plants showing [1]				Degree of systemic infection caused by—	
	Local lesions caused by—		Systemic infection caused by—			
	Pod mottle virus	Southern bean mosaic virus	Pod mottle virus	Southern bean mosaic virus	Pod mottle virus	Southern bean mosaic virus
Green-podded snap beans (bush)—Con.						
Refugee, Stringless Green	[3] +	−	−	+		Mild.
Refugee, U. S. No. 5	[3] +	−	−	+		Do.
Rival	[3] +	−	−	+		Do.
Sensation Green Pod	[3] +	−	−	+		Do.
Tendergreen	−	−	+	+	Severe [4]	Do.
Tenderlong	−	−	+	+	do	Do.
Tennessee Green Pod	+	+	−	−		
Valentine, Red	[3] +	−	−	+		Severe.
Valentine, Stringless Black	+	−	−	+		Mild.
Wax-podded snap beans (bush):						
Brittle Wax (Round Pod Kidney Wax)	−	−	+	+	Severe [4]	Severe.
Cherokee	−	−	+	+	do	Mild.
Davis Stringless Wax	−	±	+	∓	do	Do.
Golden Wax	±	−	∓	+	Mild	Do.
Improved Golden Wax	+	−	−	+		Do.
Improved Stringless Kidney Wax	−	−	+	+	Severe	Severe.
Pencil Pod Black Wax	−	−	+	+	do [4]	Moderate.
Puregold	−		+		do	
Sure Crop Wax	−	−	+	+	do	Severe.
Unrivalled Wax	−	−	+	+	Mild	Mild.
Green-podded snap beans (pole):						
Alabama No. 1	+	+	−	−		
Blue Lake	+	+	−	−		
Blue Lake Stringless	[3] ±	±	∓	∓	Mild	Do.
Caseknife, Dutch	+	+	−	−		
Cutshort (Red Speckled)	−	+	+	−	Mild	
Decatur	+	+	−	−		
Ideal Market	+	+	−	−		
Horticultural, French	−	−	+	+	Mild	Do.
Kentucky Wonder	+	+	−	−		
Kentucky Wonder, U. S. No. 3	+	+	−	−		
Kentucky Wonder, U. S. No. 4	+	+	−	−		
Kentucky Wonder, White	+	+	−	−		
McCaslan	+	+	−	−		
Potomac	+	±	−	∓		Do.
Wax-podded snap beans (pole):						
Golden Cluster Wax	−	−	+	+	Severe	Severe.
Kentucky Wonder Wax	+	+	−	−		
Green-podded field beans (bush):						
Kidney, Dark Red	−	−	+	+	Mild	Mild.
Kidney, White	±		∓		do	
Marrow, White	±	−	∓	+	do	Do.
Sutter Pink	−	+	+	−	do	
Green-podded field beans (pole):						
Great Northern U. I. No. 15	+	+	−	−		
Great Northern U. I. No. 123	+	+	−	−		
Pinto, Idaho	+	+	−	−		
Pinto No. 5	+	+	−	−		
Pinto No. 14	+	+	−	−		
Pinto U. I. No. 78	[3] +	+	−	−		
Red Mexican	+	+	−	−		
Robust	+	−	−	+		Do.
Small White (California strain)	+	−	−	+		Do.

[1] +, Homozygous for susceptibility; ±, heterozygous for susceptibility to local lesions; ∓, heterozygous for susceptibility to systemic infection; and −, homozygous for resistance.
[3] Veinal necrosis on inoculated leaves.
[3] Small.
[4] Necrosis of trifoliate leaves.

In many cases the local lesions produced by the pod mottle virus were much smaller than those produced by southern bean mosaic virus. This was particularly true of the Refugee varieties resistant to common bean mosaic as well as of those that have Refugee as one of their parents, such as Florida Belle, Logan, and Rival. On these varieties

the total number of local lesions per leaf was much less than on similar leaves of varieties on which the local lesions were larger. In only a few cases was necrosis associated with the systemic symptoms of southern bean mosaic, but it was common with severe systemic infection by the pod mottle virus.

Most varieties that are resistant to common bean mosaic virus are susceptible to local infection by pod mottle virus. Among such varieties are Florida Belle, Idaho Refugee, Logan, Medal Refugee, Sensation Refugee 1066, U. S. No. 5 Refugee, Ranger, Rival, Great Northern U. I. No. 15 and U. I. No. 123, Pinto U. I. No. 78, and Robust. The green-podded snap beans, except the Ranger variety, reacted differently to southern bean mosaic virus than they did to pod mottle virus (table 2).

Reaction of Lima Bean Varieties

Fifteen plants of each of five varieties of lima beans were inoculated with pod mottle virus. Two small-seeded varieties, Green-seeded Henderson Bush and U. S. 343, were susceptible to local-lesion infection only. U. S. 343 is not a true sieva type (*Phaseolus lunatus* L.), but a hybrid between Henderson Bush (*P. lunatus*) and Fordhook (*P. lunatus* f. *macrocarpus* (Benth.) Van Eselt.). Fordhook (Asgrow strain), U. S. 242, and Early Market, all large-seeded varieties, were immune.

Reaction of Other Species

Data on the host range of pod mottle virus were obtained by inoculating 5 to 10 plants of each of 25 species representing 20 genera in 9 families. None of these species became infected except soybean (*Soja max* (L.) Piper), which showed systemic infection. In most cases the mottling was very intense (fig. 4). The following varieties of soybean were susceptible: Arksoy, Biloxi, Burdette, Cherokee, Chief, CNS, Gibson, Illini, Lincoln, Ralsoy, and Virginia. All of these except Biloxi, Burdette, and Gibson were also susceptible to systemic infection by southern bean mosaic virus.

No infection was noted on any of the following species:

Apocynaceae:
Vinca rosea L. (Madagascar periwinkle).
Caryophyllaceae:
Dianthus superbus L. (lilac pink).
Silene compacta Fisch. (oriental silene).
Chenopodiaceae:
Beta vulgaris L. (beet, var. Detroit Dark Red).
Compositae:
Callistephus chinensis (L.) Ness (China-aster).
Lactuca sativa L. (lettuce, var. Grand Rapids).
Cruciferae:
Brassica oleracea var. *botrytis* L. (broccoli).
Cucurbitaceae:
Cucumis sativus L. (cucumber, var. Colorado).
Leguminosae:
Melilotus alba Desr. (white sweetclover).
Phaseolus angularis (Willd.) W. F. Wight (adzuki bean).
Phaseolus aureus Roxb. (mung bean).
Phaseolus coccineus L. (scarlet runner bean).
Phaseolus mungo L. (urd bean).
Pisum sativum L. (pea, var. Little Marvel).
Trifolium incarnatum L. (crimson clover).
Vicia faba L. (broadbean).

Leguminosae—Continued
Vigna sesquipedalis (L.) Fruwirth (asparagus-bean).
Vigna sinensis (Torner) Hassk. (cowpea, var. Chinese Red).
Geraniaceae:
Pelargonium hortorum Bailey (geranium, var. Rosina).
Solanaceae:
Capsicum frutescens L. (pepper, var. California Wonder).
Datura stramonium L. (jimsonweed).
Lycopersicon esculentum Mill. (tomato, var. Marglobe).
Nicotiana glutinosa L.
Nicotiana tabacum L. (tobacco, var. Turkish).

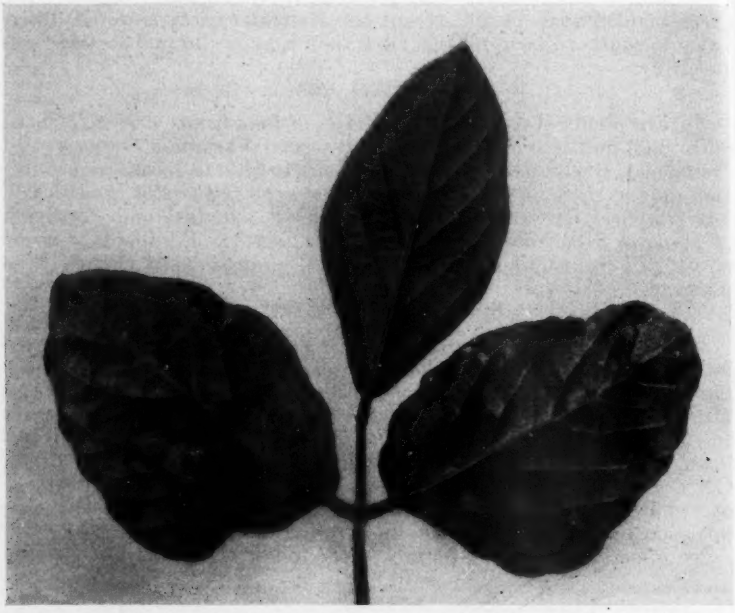

FIGURE 4.—Mottling of a leaflet of the Biloxi soybean produced by pod mottle virus.

DISTRIBUTION OF POD MOTTLE VIRUS IN INFECTED PLANTS AND SEED TRANSMISSION

Pod mottle virus was isolated from all parts of the bean plant including the roots, as was southern bean mosaic virus (*7*). Common bean mosaic virus has not been isolated from the roots of infected plants (*2*). Macerated seeds in the green stage taken from plants systemically infected by pod mottle virus produced abundant local lesions when inoculated to Pinto. The virus was not recovered from seeds in the milk and dry stages. Approximately 150 seeds harvested from plants of several systemically infected varieties and planted in the greenhouse produced no infected plants. Macerated seeds from plants systemically infected by southern bean mosaic virus and stored for 4½ months produced severe local infection on Pinto. Seeds from similar plants stored for 7 months before planting in the greenhouse

produced all healthy plants. It thus appears that neither pod mottle virus nor southern bean mosaic virus is important from the standpoint of seed transmission.

PROPERTIES OF POD MOTTLE VIRUS

Juice from relatively young systemically infected bean plants was used for all of the studies of physical properties. The results were based on local lesions produced on the Idaho Pinto variety of bean. In all cases the properties of pod mottle virus were compared with those of southern bean mosaic virus. Since the results obtained with the latter virus were very similar to those reported earlier (*7*) only one trial was made with it. Two trials were made with the pod mottle virus.

Thermal Inactivation

The thermal inactivation points for the pod mottle virus were between 70° and 75° C. when it was heated for 10 minutes (table 3). This temperature is lower than that for southern bean mosaic virus inactivation, which was shown earlier (*7*) to be between 90° and 95°. Pod mottle virus, however, resists higher temperatures than the common and yellow bean mosaic viruses, which are inactivated between 56° and 58° (*4, 8*).

Table 3.—*Comparison of thermal inactivation points of pod mottle virus and southern bean mosaic virus, as determined by production of local lesions per leaf on the Idaho Pinto variety of bean*

[Averages based on 24 leaves]

Temperature (°C.)	Lesions produced by—		
	Pod mottle virus		Southern bean mosaic virus (trial 1)
	Trial 1	Trial 2	
	Number	*Number*	*Number*
Not heated	(1)	(1)	(1)
60	90	250	280
65		120	
70	4	16	70
75		0	
80	0		70

[1] Numerous.

Tolerance to Dilution

The maximum dilution at which infection by pod mottle virus occurred was 1 to 10,000 (table 4). Southern bean virus was still infectious at a dilution of 1 to 500,000. The only other virus thus far reported that produces local lesions on beans and that has approximately the same dilution end point as pod mottle virus is the tobacco necrosis virus reported by Smith and Bald (*5*). No apparent relationship exists between these two viruses.

Aging

Local lesions were produced by expressed bean juice containing pod mottle virus after storage for 62 days at 18° C., but not after 93 days (table 5). Southern bean mosaic virus was infectious after 93 days at 18°, and in a previous paper (*7*) it was reported still infectious after

32 weeks. When held at room temperature for 25 days, pod mottle virus lost its infectivity.

TABLE 4.—*Comparison of tolerance to dilution of pod mottle virus and southern bean mosaic virus, as determined by production of local lesions on the Idaho Pinto variety of bean*

Dilution	Pod mottle virus				Southern bean mosaic virus (trial 1)	
	Trial 1		Trial 2			
	Leaves inoculated	Total lesions	Leaves inoculated	Total lesions	Leaves inoculated	Total lesions
	Number	*Number*	*Number*	*Number*	*Number*	*Number*
None	12	[1]	15	[1]	6	[1]
1 to 1,000			15	900		
1 to 10,000	12	3	16	2	12	125
1 to 100,000	12	0			12	89
1 to 500,000	12	0			10	45

[1] Numerous.

TABLE 5.—*Comparison of resistance to aging in vitro of pod mottle virus and southern bean mosaic virus, as determined by production of local lesions on Idaho Pinto variety of bean*

Time aged at 18° C.	Pod mottle virus		Southern bean mosaic virus	
	Leaves inoculated	Total lesions	Leaves inoculated	Total lesions
	Number		*Number*	
0	18	Numerous	18	Numerous.
10 days	12	do	12	Do.
35 days	20	do	20	Do.
62 days	24	Very few	24	Moderately numerous.
93 days	20	None	20	Few.

TABLE 6.—*Comparison of tolerance to exposure to chemicals for 30 minutes of pod mottle virus and southern bean mosaic virus, as determined by production of local lesions on the Idaho Pinto variety of bean*

Chemical	Concentration of chemical	Pod mottle virus		Southern bean mosaic virus	
		Leaves inoculated	Total lesions	Leaves inoculated	Total lesions
		Number	*Number*	*Number*	*Number*
None		16	2,500–3,000	16	4,000–5,000
Alcohol	50 percent	20	21	18	397
Do	75 percent	16	14	20	139
Do	95 percent	16	2	14	87
Nitric acid	1 to 250	20	0	18	189
Do	1 to 100	22	0	12	11
Do	1 to 50	20	0	20	0
Do	1 to 25	20	0	18	0
Formaldehyde (37 percent)	1 to 1,000	12	2,500–3,000	12	2,500–3,000
Do	1 to 500	12	2,500–3,000	12	2,500–3,000
Do	1 to 100	12	700–800	12	25
Sodium chloride	2.5 percent	12	2,000–2,500	12	3,000–4,000
Do	5 percent	12	700–800	12	2,000–3,000
Do	10 percent	12	[1]	12	1,000–1,500

[1] Leaves seriously burned; impossible to determine whether virus was inactivated.

Inactivation by Chemicals

Pod mottle and southern bean mosaic viruses were treated with each of several chemicals for 30 minutes. In general they did not show outstanding differences in reaction to any of the chemicals except nitric acid, which inactivated pod mottle virus at all dilutions tested (table 6). The different percentages of alcohol reduced local-lesion production by pod mottle virus more than that by southern bean mosaic virus. Formaldehyde (1 to 100) had less effect on pod mottle virus than it did on southern bean mosaic virus. A 10-percent sodium chloride solution injured the inoculated leaves so seriously that it was impossible to determine whether pod mottle virus was actually inactivated. Common and yellow bean mosaic viruses were inactivated more readily than pod mottle virus by all the chemicals used except nitric acid; these three viruses reacted rather similarly to this acid (*4, 8*).

Immunological Studies

Although the evidence obtained showed no relationship between pod mottle virus and southern bean mosaic virus, immunological studies were made to determine definitely whether such a relationship does exist.

Ten plants of each of the following bean varieties were inoculated with southern bean mosaic virus: Stringless Black Valentine, Bountiful, Burpee Stringless Green Pod, Dixie White, and Improved Golden Wax; all showed systemic infection on the trifoliate leaves. All of these varieties are susceptible to local-lesion infection by the pod mottle virus. After the systemic symptoms of southern bean mosaic were observed, mottled leaves from all of them were inoculated with pod mottle virus. Within 3 days typical local lesions of the pod mottle virus were noted on the inoculated trifoliate leaves.

The Cutshort variety is susceptible to local-lesion infection by southern bean mosaic virus but is resistant to local-lesion infection by pod mottle virus. Ten plants of that variety were inoculated with pod mottle virus; after systemic infection was noted, mottled leaves were inoculated with an extract of southern bean mosaic virus. After 3 or 4 days local lesions typical of southern bean mosaic virus were observed. This, together with the local-lesion production by pod mottle virus on leaves systemically infected by southern bean mosaic virus, shows that southern bean mosaic virus does not protect against pod mottle virus and vice versa, furnishing additional evidence that no relationship exists between these two viruses.

In routine inoculations many plants of several varieties showing the mottle symptoms of common bean mosaic virus resulting from seed-borne infection were inoculated with pod mottle virus. Among the varieties inoculated were Bountiful, Burpee Stringless Green Pod, Idaho Pinto, and Stringless Green Refugee. Local lesions of pod mottle virus developed on all, showing that common bean mosaic virus does not protect against pod mottle virus.

Separation of Pod Mottle Virus from Other Bean Mosaic Viruses

In an earlier paper (*7*) it was shown that common, yellow, and southern bean mosaic viruses can readily be separated from each other. Pod mottle virus can be separated from a mixture of common and yellow bean mosaic viruses by diluting the virus extract more than 1 to

2,000. This will inactivate the last two viruses, but not pod mottle virus. Aging a virus-extract mixture for more than 2 days at 18° C. will also separate the pod mottle virus from the other two. Common and yellow bean mosaic viruses lose their infectivity in vitro after 24 hours at 18°, whereas pod mottle virus is infectious for about 60 days at this temperature. Pod mottle virus can also be separated from yellow bean mosaic virus by inoculating soybeans, which are susceptible to the former virus but resistant to the latter.

Pod mottle virus can be separated from southern bean mosaic virus by inoculating the Cutshort or the Sutter Pink varieties of bean. Both of these varieties are susceptible to systemic infection by pod mottle virus, but resistant to systemic infection by southern bean mosaic virus. Southern bean mosaic virus can be separated from pod mottle virus by inoculating Bountiful, Burpee Stringless Green Pod, and several other varieties that are susceptible to systemic infection by southern bean mosaic virus but resistant to systemic infection by pod mottle virus. It can also be separated from pod mottle virus by heating the virus mixture above 75° C. or by diluting it to 1 to 500,000. The pod mottle virus is not infectious at these points, but southern bean mosaic is.

DISCUSSION

Pod mottle virus appears to be distinct from any other virus reported on beans. Zaumeyer and Harter (*6*, *7*) described southern bean mosaic virus, which pod mottle virus most closely resembles. On most varieties the local lesions produced by these two viruses are dissimilar. Furthermore, the physical properties of southern bean mosaic virus are unlike those of pod mottle virus.

Chamberlain (*1*) reported a pea streak virus which produced local lesions on beans somewhat similar to those produced by pod mottle virus. Differences in systemic symptoms, certain physical properties, and host range distinguish it from pod mottle virus.

The tobacco necrosis virus of Smith and Bald (*5*) also produces on beans local lesions which can be mistaken for those produced by pod mottle virus, but the fact that tobacco necrosis virus is not systemic in beans and has a much wider host range than pod mottle virus readily distinguishes it from this virus. It is of interest, however, that the thermal inactivation and dilution end points of the two viruses are similar. None of the other viruses thus far reported that produce local lesions on beans (*7*) show a close relationship to pod mottle virus.

All of the varieties of beans susceptible to local infection by pod mottle virus like those susceptible to southern bean mosaic virus can be considered commercially resistant, since the damage caused by local infection if found under field conditions would be negligible. Fortunately, many of the popular varieties of green-podded bush and pole snap beans and dry beans are resistant to systemic infection. There are, however, notable exceptions, especially among the green-podded bush snap beans, such as Full Measure, Landreth Stringless Green Pod, Longreen, Plentiful, and Tendergreen. These varieties are also susceptible to systemic infection by southern bean mosaic virus, but on all of them except Full Measure the symptoms produced by pod mottle virus are more severe than those produced by southern bean mosaic virus.

Since certain of the popular varieties of snap beans are susceptible to

systemic infection, pod mottle could become a menace, especially in the market garden and in some canning sections of the country where these varieties are grown. In the North where the Refugee varieties are grown for canning and in the dry-bean-growing sections of the country, the disease is not expected to be a factor, since the Refugee varieties and the majority of varieties of dry beans are resistant to the systemic infection.

Pod mottle virus is primarily restricted to *Phaseolus vulgaris*, as is southern bean mosaic virus (7). These two viruses were infectious to all varieties of *P. vulgaris* that were tested, but infectious only to *Soja max* and *P. lunatus* among the other species tested. It had been reported earlier (7) that southern bean mosaic virus infected the Virginia variety of soybean but not the Biloxi. This finding was confirmed in the present studies. In addition to the Virginia variety, several others were found to be susceptible. Pod mottle virus could become a serious virus disease of soybeans, for all of the varieties tested were susceptible to systemic infection and showed pronounced mottling.

The matter of breeding for resistance to systemic infection in susceptible varieties of snap bean would not be a difficult problem. There are a number of varieties of good commercial type that are resistant and could be used for parental material in a hybridizing program.

TECHNICAL DESCRIPTION OF THE VIRUS

Marmor valvolarum n. sp.

Common name.—Pod mottle virus.

Specific name.—From Latin valvolarum, referring to the association of the species with mottling of the pod.

Host reactions.—Local necrotic lesions induced on Idaho Pinto and other varieties of *Phaseolus vulgaris* and systemic mottle on Tendergreen and other varieties. Local necrotic lesions induced on Green-seeded Henderson Bush variety of *P. lunatus*. *P. lunatus* f. *macrocarpus* immune. Biloxi and other varieties of *Soja max* susceptible to systemic-mottle infection.

Transmission.—Readily transmitted by inoculation with expressed juice wiped on the leaves. Insect vectors not known.

Physical properties.—Inactivated between 70° and 75° C. in 10 minutes in plant juices. Dilution end point in fresh plant extract from infected bean between 10,000 and 100,000 ×. Resisted aging for 62 days at 18°, but inactive after 93 days.

Type locality.—Charleston, S. C.

SUMMARY

A new virus of bean isolated from mottled bean pods collected in South Carolina and somewhat resembling southern bean mosaic virus is described, identified, and compared with the virus of southern bean mosaic. The disease caused by this virus is designated as pod mottle. It is proposed that the virus be known as *Marmor valvolarum* n. sp.

Pod mottle virus like southern bean mosaic virus produces local lesions on some bean varieties and systemic mottle on others. A variety susceptible to local infection is immune from systemic infection, and one susceptible to systemic infection is immune from local infection.

The local lesions caused by pod mottle virus on beans are different from those caused by any other virus thus far reported. The systemic-mottle symptoms are more intense than those produced by southern bean mosaic virus. The range of symptoms includes those produced by common bean mosaic and southern bean mosaic viruses. The pod

mottle virus produces a decided mottling and considerable malformation of pods.

Pod mottle virus is readily transmitted mechanically. Young leaves are more susceptible than older ones.

The optimum temperature for the production of local lesions is 22° C. No lesions appeared at 10°.

All of the 68 varieties or strains of beans inoculated were susceptible to either local or systemic infection; of these, 41 were homozygous for susceptibility to local-lesion infection, 23 were homozygous for susceptibility to systemic infection, and 4 were heterozygous. The majority of the green-podded snap and the dry bean varieties were susceptible to local infection. Most of the wax-podded varieties were susceptible to systemic infection. The reaction of most of the green podded bush varieties of snap bean to pod mottle virus was different from that to southern bean mosaic virus. Most of the green-podded pole varieties and the dry bean varieties showed the same reaction to both viruses. Practically all of the varieties resistant to common bean mosaic virus were susceptible to local infection by the pod mottle virus.

The sieva lima bean (*Phaseolus lunatus*) and a hybrid between *P. lunatus* and *P. lunatus* f. *macrocarpus* were susceptible to local infection of the pod mottle virus, but the Fordhook types were immune.

Eleven varieties of soybean were the only other susceptible hosts found among 25 species, representing 20 genera in 9 families.

The pod mottle virus was inactivated between 70° and 75° C. when heated for 10 minutes. It was active at a dilution of 1 to 10,000, but not at 1 to 100,000. It resisted aging for 62 days at 18°, but after 93 days it was inactive. The virus was not inactivated by 95-percent alcohol after a 30-minute treatment, but a 1 to 250 solution of nitric acid destroyed it. It was still infectious after being treated for 30 minutes in a 1 to 100 solution of 37-percent formaldehyde. A 5-percent sodium chloride solution did not inactivate the virus after 30 minutes.

Immunological studies showed no relationship between the pod mottle, southern, and common bean mosaic viruses.

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